POWERFUL GAMMA RAY SPLASHES, A NEW ASTRONOMICAL DISCOVERY

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16. Abstract

The discovery of powerful gamma ray outbursts by satellite vehicle is reported. The outbursts being determined not to originate in the Solar System, the question of the origin of these bursts is examined.

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POWERFUL GAMMA RAY SPLASHES, A NEW ASTRONOMICAL DISCOVERY

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A few months ago astronomers noticed a new phenomenon, the nature of which /93* was unclear, but the size of which was so great that here apparently is concealed something no less significant for science than was the discovery of quasars, relict radiation and pulsars. On special artificial Earth satellites short-term γ ray streams were recorded of such great power that they could only have originated in some kind of grandiose cosmic process.

Four of the special satellites of the special Vela series were put into a circular orbit with a radius of ~ 100,000 km by the USA. Six γ quantum detectors were installed on each of the satellites, making it possible to record sources in the celestial sphere in any direction. The recording electronic equipment has a time resolution of ~ 0.01 seconds, and this makes it possible to obtain a rather exact time passage of γ radiation intensity. The energy of the γ quantum recording apparatus lies within the limits of 0.2 and 1.5 mev.

The possibility of simultaneous recording of bursts on 2 or more satellites guarantees the physical nature of bursts, whereas with one satellite it is impossible to exclude the activity of random causes in the apparatus. The possibility of coincidence in time and nature of such coincidences for 2, 3 and even more for 4 satellites is negligibly small. In addition an essential advantage of the Vela satellite series is the possibility of quite closely determining the direction from which photons come by the time interval in recording the leading γ front.

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[4]Institute of Space Research of the Academy of Sciences.
[5]Vela means sail (Latin).
*Numbers in the margin indicate pagination in the foreign text.

Let us explain this method of determining the direction (in somewhat more detail (Figure 1). First let us examine a case with two photon detectors separated by a sufficiently large distance $l \gg c\tau$ (where c is the counting rate and $\tau \sim 0.01$ seconds, indeterminate time measurement). Then the distance in time $\Delta\tau$ of registration of x-ray radiation arrival determines the angle ϑ between the direction of photon distribution and a straight line connecting the detectors:

$$\cos\vartheta = c\Delta t / l.$$

Since $\Delta\tau$ and l are determined by experience, the angle ϑ can be computed according to this formula. This means that the source of the burst is found within some circle located on the celestial sphere.

Let us further examine the simultaneous recording of bursts by 3 detectors. In this case the direction for the source is found at the intersection of 2 circles, i.e., it corresponds to two points on the celestial sphere. Finally, simultaneous readings of 4 or more detectors unambiguously defined the direction to the source of the γ burst.

The precision in defining the angular coordinates depends on precision in measuring the time differential (basically this distance is close to the value of τ), on the distance between the artificial Earth satellites and on the time development of the pulse at the moment of burst, which is approximately equal to 0.1 second[6].

After 3 years of observation by colleagues in the Los Alamos Laboratory [1], Sixteen bursts were fixed and recorded by more than one satellite. An analysis of the results showed that the sources of the x-rays causing the radiation bursts could not be located on Earth, the Moon or the Sun. It was also possible to determine that the sources were not necessarily located in the galactic plane. In addition the angular distribution of the sources does not contradict the assumption of their isotropism, although the statistical reliability of such

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[6] In addition to 4 artificial Earth satellites of the Vela system, we managed to use 2 other instruments recording γ quanta for one case. Processing the data from satellites made it possible to determine the direction of the source of the γ bursts with a precision of $\sim$ (4-5) degrees of arc.

[7] R. W. Klebesadel, I. B. Strong and R. A. Olsen, Astrophysical J. Lett., Volume 182, L. 85, 1973.

a conclusion is not great. Thus, either the sources are weak and located in the same spiral branch of the Galaxy as the Sun, or they are very powerful and located in other galaxies.

The bursts lasts from 1 to 10 seconds with a very abrupt front, less than 0.05 seconds (Figure 2). It posssesses a microstructure with minimum duration of about 0.1 second. The intensity of radiation is so great that it justifies the term grandiose γ ray burst. If such an intensity were to be realized in the optic range, these bursts would be visible in the sky many times brighter than any star or planet, although their brightness would not equal that of the Moon. The maximum intensity of the γ bursts goes as high as $\sim 10^{-3}$ erg/cm^2. •sec, and the full flow 1 after all burst time amounts to 10^{-4}-10^{-5} erg/cm^2.

But where could these sources of bursts be located? Let us first look at the first suggestion: the sources are found in one of the spiral branches of the Galaxy with the Sun, i.e., at distances smaller than the magnitude of the minor axis of the Galaxy ($\sim$ 500 parsecs).

From the very beginning it is necessary to eliminate main sequence type stars like our Sun. During solar flares γ radiation intensity is approximately 5 orders less than the intensity of optic radiation. Full release of energy by the sources of γ radiation after burst time is established by the formula: $L \sim 4\pi IR^2$, where R is the distance to the source. Setting R = 10 parsec $\simeq 3 \cdot$ $\cdot 10^{19}$ cm, we find that $L \sim 10^{35}$-10^{36} erg. Then the energy release in the optic field, if the analogy with solar radiation is maintained, would reach an enormous magnitude $\sim 10^{40}$-10^{41} erg and such a flare could not help being noticed. On the other hand, full energy release during solar flares do not exceed 10^{32} erg. According to all of these considerations quiet stars of the type of the Sun could not possibly be the cause of gigantic γ bursts.

A more complex question in observed γ bursts is the participation of red dwarfs of the type UV Ceti (the closest star of this type to us is UV Ceti itself, located at a distance of $\sim$ 2 parsecs from the Sun)[8]. Stars of this type

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[8]A Soviet astrophysicist, G. A. Guzradyan, has already written about the possibility of flares on red giants in the γ range, Astronomy and Astrophysics, Volume 13, p. 348, 1971.

differ greatly in having little luminosity ($\sim 10^{29}$ erg/sec, which is approximately 4-5 orders less than the luminosity of the Sun), but it is significant that very often their luminosity in the optic range increases greatly [2], sometimes more than 100 times (during flares the luminosity of the Sun increases by 0.01). The time of such a flare is about 1 minute, which corresponds with the time of γ flares in order of magnitude. Recently, during flares on red dwarfs, notice was also taken of radio emission of an intensity approximately 1,000 to 10,000 times smaller than the intensity in the optic range.
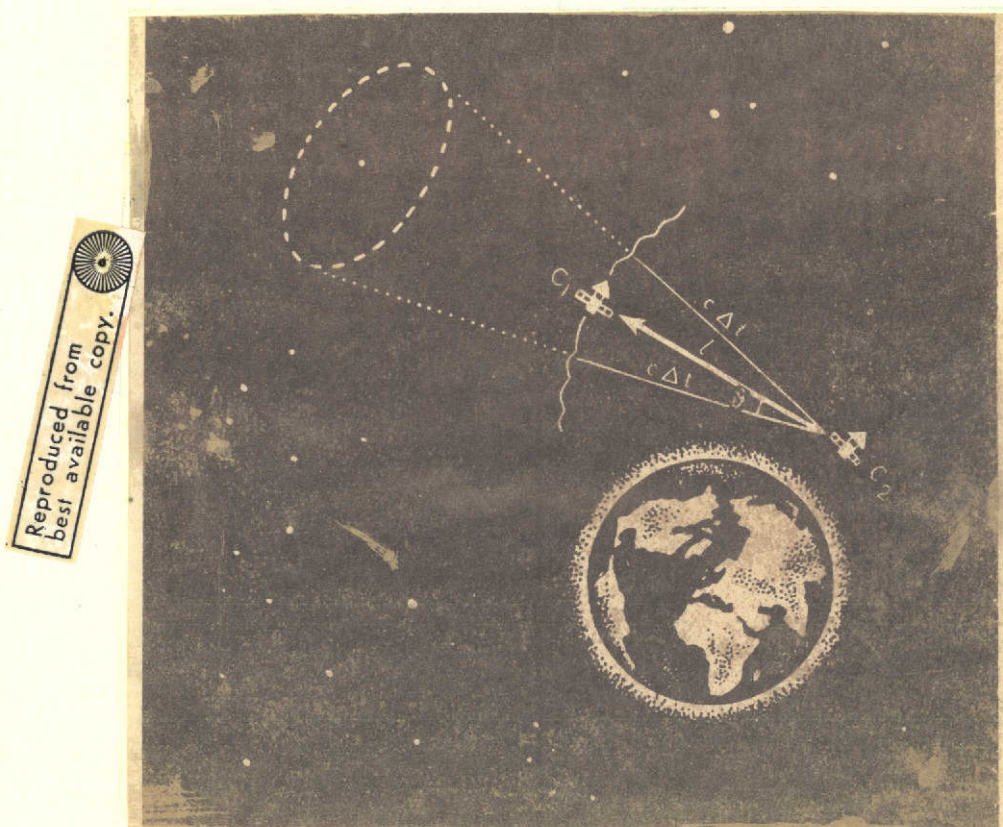
Figure 1. The Leading Front of the γ Blast is Recorded at the Beginning by Satellite C_1, and After Time Δt by Satellite C_2. If the distance l between the satellites is known, it is possible to determine the angle ϑ between the direction of the γ blast source and the straight line segment connecting satellites C_1 and C_2: $\cos \vartheta = c\Delta t/l$, c is the counting rate in a vacuum. Angle ϑ indicates on the celestial sphere the circle in which the source of the γ rays is found.

If we interpolate the spectrum of radiation from red dwarf flares between the radial and optic range by means of the exponential function, and then extrapolate this function to the energy of γ quanta (E ~ mev), we will get in this range energy ~ 10^{35} erg, which approximately coincides with the energy released during the flares from the source located at a distance of ~ 10 parsecs.

However, a series of difficulties arises in this type of interpretation. First, some properties of the energetic spectra of red dwarf flares are close to the characteristics of solar flare spectra. Secondly, there is no certainty regarding the possibility of an approximate description of flare spectra with the exponential function in a sufficiently large energy interval. And finally the last thing (in calculation, but not in importance): at present the mechanism for forming large relativistic electron currents in red dwarfs is unknown. But if all spectra from radio to γ rays are explained by one mechanism, there might be only quantum radiation by relativistic electrons in the magnetic field (the so- /95 -called synchrotron or magnetic cyclotron radiation).

The second galactic population, which could be called on to explain γ flares, turns out to be magnetic stars with an external magnetic field intensity ~ 10^4-10^5 erg. However, observations of magnetic stars have shown that they probably are some of the most "quiet" stars. Irregular changes in their luminosity are insignificant (less than 1%). In addition phenomena accompanying solar flares (the appearance of emission lines, etc.) have not been observed on magnetic stars. All of this makes any hypothesis above magnetic stars being sources of γ bursts extremely improbable.

So, among the stars in our Galaxy there are no successful candidates for explaining this new riddle.

If the sources of the γ bursts are found outside the boundaries of our Galaxy, the energetic requirements for them increase considerably. Thus, for example, if a source is found at a distance of 1 Mps (the mean distance to neighboring galaxies), the full energy release after a flare, computed by the same formula, would have to amount to 10^{46} erg. This magnitude approaches the full energy release in supernova flares (10^{49}-10^{51} erg) [3]. The hypothesis about

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bursts connected with supernova flares outside our Galazy served as an impulse to seek such events, but investigators did not find anything like what had been Predicted. Actually the duration of bursts in a model of supernova flare, developed by S. Colgate [4], is very short ($\sim 10^{-5}$ seconds), while the photon energy is great ($\sim 1,000$ mev). Therefore, even if γ bursts are connected with supernova explosions in other galaxies, the bursts mechanisms remain completely obscure.

We propose an interesting possibility of explaining γ flares by the collapse of rotating magnetic stars of mass $\sim 10^5$ $M_\odot$. The presence of these stars deep in the Seifert \galaxies also apparently determines their activity. When such surface mass stars collapse, the external magnetic field is changed. Consequently it is possible that particles of plasma revolving around such a star accelerate under the influence of an induced electrical field. The acceleration of the particles radiates γ quanta in interaction with the magnetic field of the galactic cores (e.g., in the process of synchrotron radiation). This hypothesis could explain both the energetic spectrum and the flare statistics, since in the size of the radius of several thousand megaparsecs the expected number of collapsing cores in the Seifert galaxies per |year by order of magnitude coincides with the observed number of γ flares. In this case the energy released during collapse exceeds the necessary energy of γ sources by several orders.

It is still not possible to identify with certainty the sources of γ bursts with any known cosmic objects, and therefore this will certainly stimulate intense observation and theoretical research.

Factors which could clear up the problem of γ burst origin could include more detailed observation of the spectra of red dwarf flares and specification of the characteristics of Seifert |galaxy cores and of supernova explosions. Synchronous coverage of the celestial sphere in the optic and γ ranges is very important. However, the most important experimental problem appears to be increasing the sensitivity of instruments. Statistical data, improved by measurements with sensitive instruments, makes possible a choice between galactic and metagalactic hypotheses about the nature of γ bursts. For example, the

distribution of weak galactic γ bursts should be anisotropic. But any hypothesis must satisfactorily describe everything known about γ bursts, and observers will find more and more new data which, in the long run, will come to an end at one of the hypotheses.
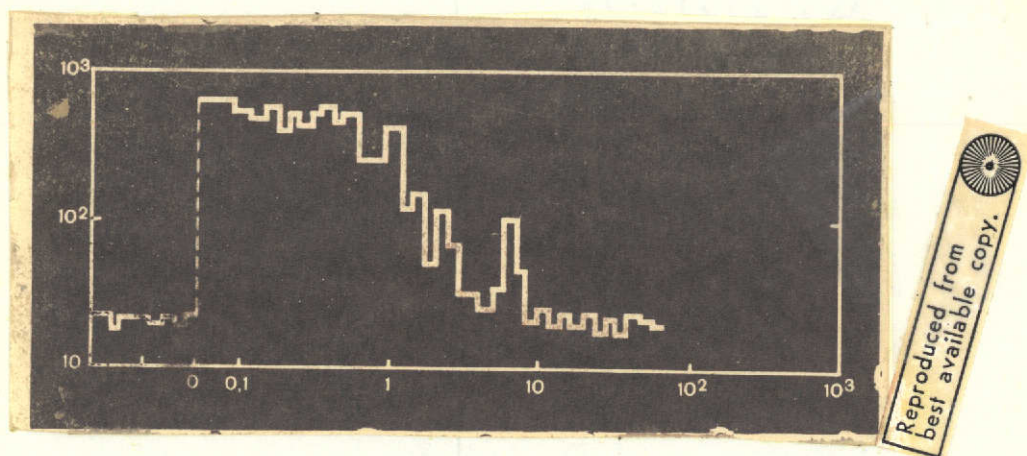
Figure 2. Counting Rate of N γ Quanta as a Function of Time for Burst, Observed 22 August 1970. On the axis of the abscissa it is found the logarithm of time in seconds, and on the ordinate axis the logarithm of number of γ quanta recorded per second. The increase in γ quanta flow occurs so sharply that the structure of the wave front (shown by the line of dashes) cannot be developed.

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